SEALS FOR 5200 PSI AIR SYSTEMS

FINAL REPORT

Project No. S-F013-13-01

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RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD

VALLEJO, CALIFORNIA

Report No. 28-10

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ABSTRACT

The objectives of this investigation were (1) to develop elastomeric seals for 5200 psi air systems wherein the compressors are lubricated with either petroleum-base fluids or with phosphate-ester fluids conforming to specification MIL-H-19457, and (2) to prepare a specification for these seals.

A Viton B stock (377-112) was previously developed and shown by performance tests to be very suitable for the purpose. However, O-rings of this stock corroded steel and bronze under humid conditions. This problem was solved by washing the O-rings with soap and water prior to placing them in contact with the metals.

Dynamic and static performance tests of 377-112 O-rings lubricated with dry molybdenum disulfide verified the suitability of this stock and showed that this lubricant was as satisfactory as MIL-L-4343A grease currently used in high pressure air systems. The use of the dry molybdenum disulfide lubricant would eliminate the possible explosion hazard incurred by the use of MIL-L-4343A grease.

Specimens of stock ML-G-522 developed by the Material Laboratory, New York Naval Shipyard, swelled excessively after exposure to 5200 psi air and blistered when subjected to a performance test The stock was therefore considered unsatisfactory for use in seals for 5200 psi air systems.

A specification was prepared based on tests conducted on specimens of stock 377-112.

ester conforming to specification MIL-H-19457, reference (b). The seals must, therefore, be compatible with both fluids as well as compressed air.

2. The work was to be accomplished in two phases. Phase 1 comprised the development of seals for use in 5200 psi air systems, and Phase 2, the development of seals suitable for 12,500 psi systems. Reference (a) requested that a proposed specification for the seals be written which would include a cycling endurance test. Reference (c) deleted the requirement for a cycling endurance test.

3. When rubber seals are subjected to high pressure air, they absorb air in proportion to the pressure. If the seal is suddenly decompressed after exposure for several hours, it will swell due to effervescence of the air dissolved in the rubber. The amount of swelling is limited by the strength and rigidity of the rubber. If the swelling is great enough, the seal will be so weakened by the formation of air-filled pores that rupture or extrusion of the seal will occur when it is again subjected to high pressure air. Seals for this service must therefore have sufficient strength and rigidity to prevent such excessive swelling.

4. This is the final report of phase 1 of this investigation; the previous reports were references (d) through (j). A summary of the findings from these reports is given in the following paragraphs:

a. Seals prepared from Viton B are satisfactory for high pressure air service and are judged superior to those of Viton A-HV in respect to processing on factory equipment. Seals of the two rubbers are equal in resistance to swelling by both types of compressor lubricants and by high pressure air.

b. Class B (70 Shore A) O-rings of MIL-P-5516B, reference (k), are unsuitable for use in 5200 psi service. Class A (90 Shore A) O-rings have marginal suitability for this service, provided petroleum-base lubricants are used in the compressor.

c. Simulated service tests were run on 70, 80, and 90 Shore A Viton B O-rings. All O-rings sealed satisfactorily, but the 70 Shore A O-rings exhibited excessive swell. The best stock tested was a 90 Shore A Viton B compound, 377-112.

d. When O-rings of stock 377-112 were subjected to a corrosion test similar to that in Specification MIL-P-5516B, they were found to corrode steel and brass under the humid test conditions. This stock could not, therefore, be judged completely satisfactory for making seals for high pressure air systems until its corrosiveness could be controlled.

5. This report presents the following information:

a. A method for preventing corrosion of metals by Viton vulcanizates.

b. A comparison of O-rings of stock 377-112 with O-rings of Material Laboratory (New York Naval Shipyard) stock ML-G-522.

c. A comparison of MIL-L-4343A grease with dry molybdenum sulfide for lubricating seals in high pressure air systems.

d. A proposed specification for seals for high pressure air, and the results obtained when specimens of stock 377-112 were subjected to the specification tests.

PREVENTION OF CORROSION

6. As stated above the best stock developed by the Laboratory for seals for 5200 psi air service is 377-112. The recipe for this stock is as follows:

Stock 377-112

Viton B	100
Thermax	10
Philblack E	15
Maglite D	15
Stearic acid	0.5
Di-isooctyl sebacate	3
Diak No. 3	4

CURE: 30 min. at 300°F in press, plus 1 hr. at 200°, 250°, 300°, 350°, and 400°F in oven, plus 24 hrs. at 450 F in oven.

7. The physical properties of this stock are excellent. In addition, O-rings of this stock successfully passed the simulated service test described in Report 28-9, reference (j). However, as stated previously, O-rings of this stock corroded steel and bronze plates when subjected to a corrosion test similar to that in specification MIL-P-5516B and described in Report 28-9. Essentially, this test consisted of humidifying O-rings with ambient air of 100% relative humidity for 72 hours, dipping them in Cellulube 220, and clamping the wet O-rings between polished metal plates of steel, bronze, brass, and aluminum for 96 hours at 100% relative humidity.

8. Since Report 28-9 was issued, it was found that this tendency to corrode steel and bronze was common to all Viton stocks and could not be eliminated by any of a number of compounding variations tried. However, it was discovered that corrosion could be completely eliminated by simply washing the O-rings with soap and water after humidification and just before clamping between the polished test plates. No corrosion occurred even when the time of contact of the plates with Viton B O-rings was extended from 96 hours (4 days) to 60 days. The stocks studied and the test procedures used are given in detail in Report 92-13, reference (l). It was verified that this washing procedure also eliminated the corrosiveness of 377-112 O-rings, as shown by the results given in Appendix 4.

COMPARISON OF STOCK 377-112 AND STOCK ML-G-522

9. The Material Laboratory, New York Naval Shipyard, in reference (m) described a Viton B stock (ML-G-522) which they recommended for high pressure air service. The recipe of this stock is given below:

Stock ML-G-522

Viton B	100
Thermax	45
Maglite D	15
Di-isooctyl sebacate	5
Diak No. 3 (LD-214)	4

CURE: 30 min. at 300°F in press, plus 1 hr. at 200°, 250°, 300°, and 350°F in oven, plus 24 hrs. at 400°F in oven.

10. Specimens were cured from this stock and from Rubber Laboratory stock 377-112 (recipe in paragraph 6). The specimens were then submitted to the tests listed below with the indicated results:

Test	ML-G-522	377-112
Tensile strength, psi	1900	2190
Ultimate elongation, %	160	140
Stress at 100% elongation, psi	1260	1630
Shore A hardness, 15-second reading	83	88
Volume change, after 168 hours at 212°F in Cellulube 220, %	+5	+5
Volume change, after 168 hours at 212°F in Cellulube 220, plus 168 hours at 74°F in 5200 psi air, measured 1 hour after decompression, %	+15	+9

11. The tests were run on AN6230-7 O-rings except for hardness, which was measured on 1/4-inch thick by 2-inch diameter specimens. The test procedures used were the same as those given in paragraph 19.

12. It was the opinion of the Rubber Laboratory that the swell of the ML-G-522 O-rings after exposure to high pressure air was excessive, and that suitability

of this stock for making high pressure air seals was questionable. O-rings of stock ML-G-522 were submitted, therefore, to the simulated service test developed by the Rubber Laboratory and described in detail in Report 28-9. Briefly, the test apparatus consists of a steel cylinder closed at both ends with steel caps fitted with AN6230-7 O-rings of the stock being tested. These serve as static seals (gaskets). An aluminum piston fitted with an AN6227-27 O-ring of the stock being tested at either end, slides back and forth in the cylinder. These O-rings are dynamic seals (packings). The space between the two dynamic seals is vented to the atmosphere. In operation, air at 5200 psi is introduced into each end of the cylinder. At 30-minute intervals, the pressure is released, then re-established, and the piston moved the length of the cylinder by momentarily releasing the pressure at one end of the cylinder. The test is continued 8-1/2 hours per day, five days a week, until failure or until 400 cycles have occurred. Pressure is maintained at 5200 psi overnights and weekends.

13. Prior to testing, all four of the ML-G-522 O-rings were immersed in Cellulube 220 for 94 hours at 158°F. They were then wiped with grease conforming to specification MIL-L-4343A, reference (n), to provide the necessary lubrication both for installation and for subsequent cycling.

14. None of the four O-rings leaked, and the test was terminated after 400 cycles. However, on disassembling the apparatus, it was found that all four O-rings were blistered. Appendix 1 is a photograph showing one of the blisters, and Appendix 2 is a photograph showing a cross-section of one of the blisters. As may be seen, the O-rings had suffered major damage. O-rings made from 377-112 withstood this test without blistering, as shown in Report 28-9 and in paragraph 16 below.

15. The results of the simulated service test confirmed the belief that stock ML-G-522 was not entirely suitable for high pressure air service. The results also substantiated the opinion expressed in Report 28-9 that the results of physical tests would indicate which seals were satisfactory for high pressure service, and that inclusion of a simulated service test in a specification for these seals was not necessary. The Bureau concurred with this opinion in reference (c), wherein the requirement for a performance test was deleted from the assignment.

LUBRICANTS FOR O-RINGS

16. The Laboratory has performed many simulated service tests with high pressure air on Viton O-rings and nitrile rubber O-rings lubricated with MIL-L-4343A grease without mishap. This is the grease used for lubricating seals in the high pressure air systems of submarines. However, the Bureau recently expressed concern, reference (d), over the use of MIL-L-4343A grease for lubricating the O-rings in the simulated service test because of the possibility of spontaneous combustion. The Bureau suggested the use of molybdenum sulfide as a lubricant.

17. The Laboratory has tested a total of twelve O-rings in the simulated service test apparatus using Molykote Type F, a powdered molybdenum disulfide. The O-rings were cured from stock 377-112. The tests were terminated after 400 cycles when no leaks were observed. Close examination of the O-rings revealed no damage whatever. It is concluded that Molykote is a satisfactory lubricant for this service.

18. It should be noted that these tests bring the number of 377-112 O-rings tested in simulated service to twenty-four. None has failed or shown any sign of damage. Stock 377-112 is therefore judged to be eminently suited for making seals for 5200 psi air service, since, as was mentioned earlier in this report, corrosion is no longer a problem.

PROPOSED SPECIFICATION TESTS

19. The Bureau instructed the Laboratory in reference (a) to prepare a specification for seals to be used in high pressure air service. Accordingly, a proposed specification for seals suitable for use in 5200 psi air systems was prepared and is included herewith as Appendix 3. The requirements of this specification are based on the properties of stock 377-112 and were designed to insure the suitability of candidate materials for the purpose. The properties measured and the test procedures employed in testing 377-112 are listed below. All tests were performed on AN6230-7 O-rings (0.139-inch cross-sectional diameter by 2.36-inch inside diameter) except as noted. All numbered test methods may be found in Federal Test Method Standard No. 601, reference (p).

Initial properties

Tensile strength	Method 4111. Six O-rings were tested and the average value calculated.
Ultimate elongation	Method 4121. Six O-rings were tested and the average value calculated.
Stress at 100% elongation	Method 4131. Six O-rings were tested and the average value calculated.
Hardness, Shore A	Method 3021. Specimens were 1/4 inch thick by 2 inches diameter. The 15-second reading was taken.
Permanent set	O-rings were stretched over a cone to 50% elongation, held 10 minutes, released 10 minutes, and the percent increase of internal diameter measured. Three O-rings were tested and the average value calculated.

Properties after aging 70 hours at 212°F in Air at Atmospheric Pressure, Method 7221

Tensile strength	Method 4111. Six O-rings were tested and the average value calculated.
Ultimate elongation	Method 4121. Six O-rings were tested and the average value calculated.

Stress at 100% elongation	Method 4131. Six O-rings were tested and the average value calculated.
Hardness, Shore A	Method 3021. Specimens were 1/4 inch thick by 2 inches diameter. The 15-second reading was taken.
Compression set	Method 3311. Specimens were two 1/4 inch thick discs stacked. After release from compression, the recovery time was 30 minutes at 212°F plus 30 minutes at 74°F before final thickness measurements.

Properties after aging 70 hours at 212°F in Cellulube 220

Tensile strength	Method 6111. Tensile strength was based on the swollen cross section calculated from the measured diameter. Six O-rings were tested and the average value calculated.
Ultimate elongation	Method 6111. Six O-rings were tested and the average value calculated.
Stress at 100% elongation	Method 6111. The stress was based on the swollen cross section calculated from the measured diameter. Six O-rings were tested and the average value calculated.
Hardness, Shore A	Method 3021. Specimens were 1/4 inch thick by 2 inches diameter The 15-second reading was taken. Before testing, the specimens were removed from the hot fluid and cooled in the same fluid at room temperature for 30 minutes.
Volume change	Method 6211. Three O-rings were tested and the average value calculated.

Properties after aging 70 hours at 212°F in Medium No. 3, of Method 6001

All tests and procedures were the same as those listed for Cellulube 220. Medium No. 3 oil, which is the same as ASTM No. 3 oil, was selected by the Bureau in reference (a) to represent a petroleum-base lubricant.

Volume change after 70 hours at 212°F in Cellulube 220, followed by 168 hours in air at 5200 psig, followed by release of pressure to 0 psig in 15 seconds or less

Four O-rings were immersed in the liquid and then in compressed air as indicated. One hour after decompression, the change in volume of the O-rings was calculated in accordance with Method 6211, and the results were averaged. The reason for the one hour waiting interval after decompression is explained in Report 28-9.

Volume change after 70 hours at 212°F in Cellulube 220, followed by 168 hours in air at 5200 psig, followed by release of pressure to 0 psig in 15 seconds or less

Procedure was the same as that given above for Cellulube 220.

Corrosion of metals by O-rings after contact for 96 hours at 74°F in ambient air of 100% relative humidity

The procedure in general followed that described in paragraph 4.5.6 of specification MIL-P-5516B. The procedure differed from that described in the specification in the following regards: metals used, fluids used for the wetting of the O-rings and the metal plates, and the washing of the O-rings with soap and water followed by drying. The latter operation took place immediately after humidification, and just prior to dipping the O-ring and plates into the liquid and clamping them together. The metals used and the pertinent specifications were as follows:

Aluminum alloy	QQ-A-318, Temper H32
Brass	MIL-B-994, Composition A
Bronze	QQ-P-330, Composition A
Steel	MIL-S-6758, Condition C2

This test was performed with O-rings and metal plates which had been dipped in Cellulube 220 before clamping together. It was also performed with O-rings and metal plates which had been dipped in Medium No. 3 before clamping together.

20. The results of the tests performed on stock 377-112 and the proposed specification requirements for these tests are given in Appendix 4.

FUTURE WORK

21. The development of seals for use in 12,500 psi air systems will be undertaken in accordance with the instructions in reference (a).

PERSONNEL

Bureau of Ships Project Engineer W. S. Bourn

Tests performed by R. D. Ford, Technologist

Report prepared by

R. D. Ford, Technologist

A. E. Barrett, Supervisory Technologist

Approved by

R. E. Morris, Head, Rubber Laboratory

APPENDICES

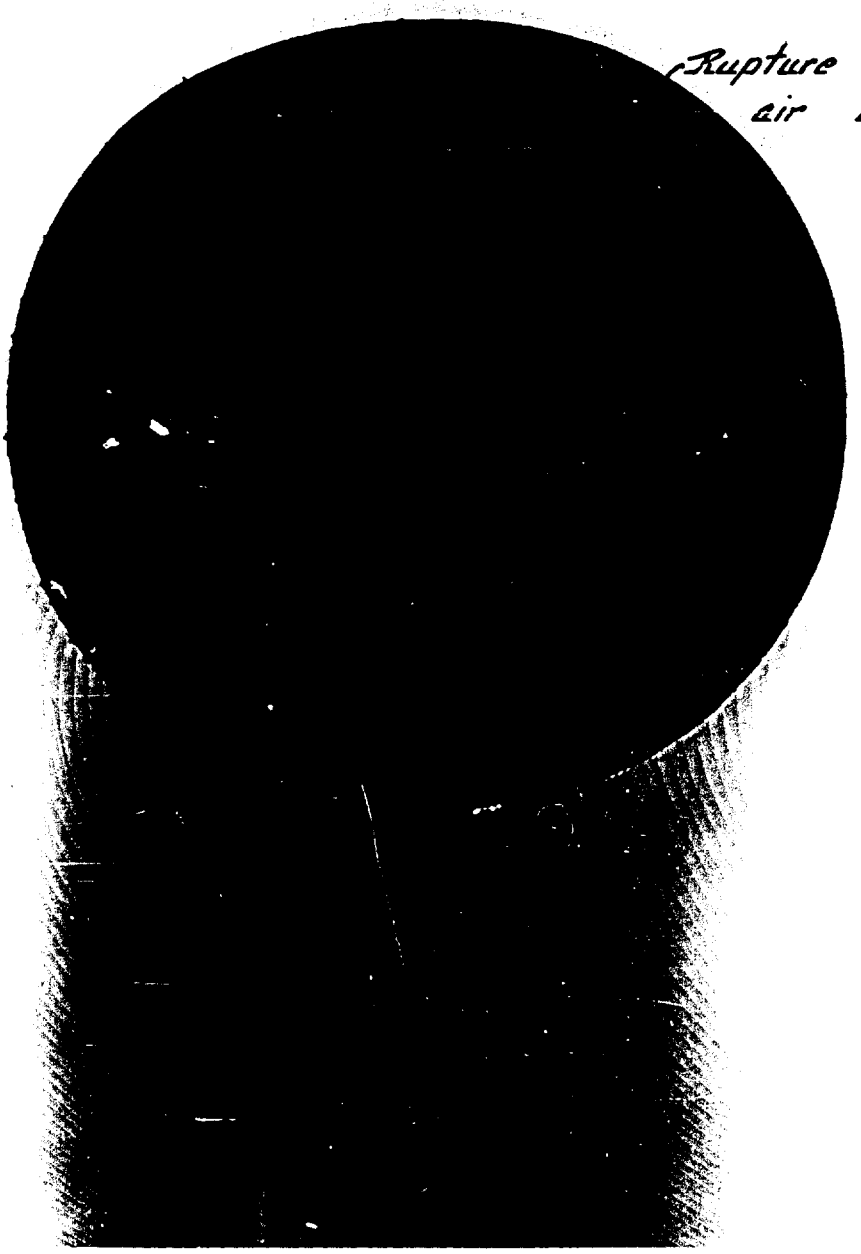
1. Photograph. Blistering of stock ML-G-522 O-ring after simulated service test in 5200 psi air (photograph no. NY9-54999-5-62).
2. Photograph. Cross section view of blistered stock ML-G-522 O-ring after simulated service test in 5200 psi air (photograph no. NY9-55000-5-62).
3. Proposed specification for seals for 5200 psi air systems having compressors lubricated with either petroleum-base of phosphate-ester fluids.
4. Table. Properties of stock 377-112 and proposed specification requirements

Distribution of report.

Abstract cards

[illegible] Stock ML-G-522 O-Ring after Simulated Service Test in 5000 psi Air. 30X

Rupture caused by air blister



CROSS SECTION VIEW OF BLISTERED STOCK ML-G-522 O-RING AFTER SIMULATED SERVICE TEST IN 5200 PSI AIR. 30X

PROPERTIES OF STOCK 377-112 AND PROPOSED SPECIFICATION REQUIREMENTS
(Sheet 2 of 2)

Tests[1]	Stock 377-112	Proposed Specification Requirements
After 70 hours at 212°F in Medium No. 3 test fluid		
Tensile strength, psi	2120	
Tensile strength, retention, %	99	Min. 85
Ultimate elongation, %	150	
Ultimate elongation, retention, %	107	Min. 85
Stress at 100% elongation, psi	1440	
Stress at 100% elongation, retention, %	94	
Shore A hardness, 15-second reading[2]	86	88±5
Change in Shore A hardness, points	-2	
Volume change, %	+2	Max. +5 Min. 0
After 70 hours at 212 F in Cellulube 220 plus 168 hours at 74°F in 5200 psi air		
Volume change, 1 hour after decompression, %	+7	Max. +10
After 70 hours at 212 F in Medium No. 3 test fluid plus 168 hours at 74°F in 5200 psi air		
Volume change, 1 hour after decompression, %	+4	Max. +10
Corrosion and adhesion after 96 hours at 100% relative humidity, specimens wet with Cellulube 220		
Steel	None[4]	None[5]
Bronze	None	None
Brass	None	None
Aluminum	None	None
Corrosion and adhesion after 96 hours at 100% relative humidity, specimens wet with test fluid Medium No. 3		
Steel	None	None
Bronze	None	None
Brass	None	None
Aluminum	None	None

(1) All tests performed on AN6230-7 O-rings except as noted.
(2) Hardness measured on 1/4-inch thick by 2 inch diameter specimens.
(4) No corrosion was evident on any of the metals when specimens were clamped for 60 days.
(5) Discoloration and staining shall not be considered detrimental if the metal surface is not roughened.

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PROPOSED SPECIFICATION FOR SEALS FOR 5200 PSI AIR SYSTEMS HAVING COMPRESSORS LUBRICATED WITH EITHER PETROLEUM-BASE OR PHOSPHATE-ESTER FLUIDS

1. SCOPE

1.1 This specification covers packings and gaskets intended for use in 5200 psi air systems having compressors lubricated with either a petroleum-base fluid or with a phosphate-ester fluid conforming to Military Specification MIL-H-19457.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification.

SPECIFICATIONS

FEDERAL

QQ-A-318	Aluminum Alloy, Plate and Sheet
QQ-P-330	Phosphor Bronze Bars, Plates, Rods, Sheets, Strips, Flat Wire, and Structural and Special Shaped Sections

MILITARY

MIL-B-994	Brass, Naval, Rods, Wire, Shapes, Forgings, and Flat Products (Flat Wire, Strip Sheet, Bar and Plate)
MIL-S-6758	Steel, Chrome-Molybdenum (4130) Bars and Reforging Stock (Aircraft Quality)
MIL-H-19457	Hydraulic Fluid, Fire Resistant

STANDARDS

FEDERAL

FED-STD-601	Rubber: Sampling and Testing

MILITARY

MS28772	Packing, D-Ring, Shock Strut

AIR FORCE-NAVY AERONATUTICAL

AN6225	Packing: V-Ring Hydraulic
AN6226	Packing: U-Cup Hydraulic
AN6227	Packing: O-Ring Hydraulic
AN6230	Gasket: O-Ring Hydraulic

3. REQUIREMENTS

3.1 Materials. The items covered by this specification shall be made from compounds which have been tested as specified herein, and which are compatible with Medium No. 3 of Method 6001, FED-STD-601, and with fluids conforming to MIL-H-19457.

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3.2 Design and construction.

3.2.1 Shape and dimensions. The shape and dimensions of D-ring packings shall conform to MS28772, V-ring packings to AN6225, U-cup packings to AN6226, O-ring packings to AN6227, and O-ring gaskets to AN6230.

3.2.2 Finish. Mold flash shall be removed from the packings and gaskets in such a manner that they conform to the requirements specified herein and on the applicable standards. Any method used to trim the mold flash on O-rings shall not remove the original mold finish of the ring over an area wider than 1/16-inch maximum adjacent to the flash.

3.2.2.1 The sealing surfaces of packings and gaskets shall not have defects such as pits, raised spots, tool marks resulting from mold imperfections, which are greater than 0.003 inch in height or depth. Such imperfections shall not be grouped closely, and shall cover not more than 10% of the surface. The entire surface of O-ring packings and gaskets shall be considered sealing surface.

3.2.2.2 The non-sealing surface of U-cup and V-ring packings shall be free from irregularities greater than ±0.010 inch, and shall contain no cuts, laps, cracks, seams, or other defects. The irregularities present shall not cause the packings to exceed the stack height tolerances.

3.2.3 Splicing. Splicing of vulcanized materials shall not be used in the manufacture of packings or gaskets.

3.3 Properties of rubber.

3.3.1 Initial properties. When tested as specified in 4.2.1, the rubber shall have the following properties:

Tensile strength, minimum, psi	1700
Ultimate elongation, minimum, psi	100
Hardness, Shore A durometer	88±5
Permanent set, maximum, %	12

3.3.2 Oven Aging. When subjected to the oven aging test specified in 4.2.2, the rubber shall have the following properties:

Tensile strength, minimum retention, %	85
Ultimate elongation, minimum retention, %	85
Hardness, Shore A durometer	88±5
Compression set, maximum, %	40

3.3.3 Aging in MIL-H-19457 fluid. After immersion in fluid conforming to MIL-H-19457, as specified in 4.2.3, the rubber shall have the following properties:

Tensile strength, minimum retention, %	85
Ultimate elongation, minimum retention, %	85
Hardness, Shore A durometer	85±5
Change in volume, maximum, %	+8
Change in volume, minimum, %	0

3.3.4 Aging in Medium No. 3. After immersion in Medium No. 3, as specified in 4.2.3, the rubber shall have the following properties:

Tensile strength, minimum retention, %	85
Ultimate elongation, minimum retention, %	85
Hardness, Shore A durometer	88±5
Change in volume, maximum, %	+5
Change in volume, minimum, %	0

3.3.5 Aging in MIL-H-19457 fluid followed by exposure to air pressure. After immersion in a fluid conforming to MIL-H-19457 followed by exposure to 5200 psig air pressure, as specified in 4.2.4, the rubber shall not increase in volume by more than 10%.

3.3.6 Aging in Medium No. 3 fluid followed by exposure to air pressure. After immersion in Medium No. 3 fluid followed by exposure to 5200 psig air pressure, as specified in 4.2.4 the rubber shall not increase in volume by more than 10%.

3.3.7 Corrosion and adhesion. When subjected to the corrosion test described in 4.2.5, the O-rings shall not corrode the specified metals sufficiently to roughen the metal surface. Staining or discoloration of the metal is permissible if the surface is not roughened. The O-rings shall not adhere to the metal surfaces.

4. QUALITY ASSURANCE PROVISIONS

4.1 Acceptance tests. Tests shall be conducted at a laboratory satisfactory to the Bureau of Ships. Tests shall measure the physical properties listed in 3.3 using the test procedures described in 4.2.

4.1.1 Sampling instructions. The acceptance test samples shall consist of the following:

51 AN6230-7 O-rings.
6 Compression set specimens 1/4-inch thick by 1.129 inches in diameter.
6 Hardness specimens 1/4-inch thick by 2 inches in diameter.

4.1.1.1 O-rings, compression set specimens, and hardness specimens shall have the same compounding and cure as the accompanying gaskets or packings.

4.2 Test procedures

4.2.1 Initial properties

4.2.1.1 Tensile strength. The tensile strength shall be determined by Method 4111 of FED-STD-601 except that specimens shall consist of six AN6230-7 O-rings. The average value shall be reported.

4.2.1.2 Ultimate elongation. The ultimate elongation shall be determined by Method 4121 of FED-STD-601 on the same specimens used in 4.2.1.1. The average value shall be reported.

4.2.1.3 Hardness. Hardness shall be measured with a Shore A durometer on molded specimens 1/4-inch thick by 2 inches in diameter, in accordance with Method 3021 of FED-STD-601 except that the hardness reading shall be taken 15 seconds after the indentor of the durometer is pressed against the specimen.

4.2.1.4 Permanent set. Permanent set shall be measured on three AN6230-7 O-rings at room temperature (75°F±5°F). The inside diameter of each O-ring shall be measured. The O-ring shall then be stretched over a cone until the inside diameter of the O-ring has been stretched 50% (1.5 times its original value). After 10 minutes the O-ring shall be removed and allowed to rest for 10 minutes, and the new inside diameter measured. Permanent set shall be calculated as the percentage increase in inside diameter. The average value shall be reported.

4.2.2 Properties after aging in atmospheric air

4.2.2.1 Tensile strength and ultimate elongation. Tensile strength and ultimate elongation shall be determined on six AN6230-7 O-rings by Method 7221 of FED-STD-601 except the aging period shall be 70 hours at 212°±2°F. The average values shall be calculated and used in computing the percent retentions of these properties after aging.

4.2.2.2 Hardness. Hardness shall be measured as in 4.2.1.3 on two specimens which have been aged for 70 hours at 212°±2°F. The specimens shall be allowed to recover at room temperature (75°+5°F) for not less than 16 nor more than 96 hours before measuring the hardness.

4.2.2.3 Compression set. Compression set shall be measured according to Method 3311 of FED-STD-601 except that three specimens shall be tested, each consisting of two molded disks 1/4-inch thick by 1.129 inches in diameter plied together. The aging period shall be 70 hours at 212°±2°F. At the end of the aging period, the specimens shall be removed from the compression apparatus and allowed to recover for 30 minutes in an oven at 212°±2°F. The specimens shall then be removed from the oven and allowed to recover for an additional 30 minutes at room temperature (75°±5°F). The final thickness shall then be measured. The average value shall be reported.

4.2.3 Properties after aging in MIL-H-19457 fluid*, or in Medium No. 3 fluid of Method 6001, FED-STD-601

4.2.3.1 Tensile strength and ultimate elongation. Tensile strength and ultimate elongation shall be measured on six AN6230-7 O-rings by Method 6111 of FED-STD-601. Tensile strength shall be based on the swollen cross-sectional diameter measured immediately before testing. The immersion period shall be 70 hours at 212°±2°F. The average values shall be calculated for use in computing the percent retention of these properties after the aging.

4.2.3.2 Hardness. Hardness shall be measured as in 4.2.1.3 on two specimens which have been immersed in the test fluid for 70 hours at 212°±2°F), then removed and cooled in a container of the same fluid at room temperature (75°±5°F) for 30±5 minutes. The specimens shall be removed, dipped momentarily in petroleum ether, blotted dry, and the hardness measured.

* Cellulube 220 is a fluid which conforms to MIL-H-19457. Cellulube 220 is sold by the Celanese Corporation of America, Chemical Division, 180 Madison Ave., New York 16, N. Y.

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4.2.3.3 Change in volume. Change in volume after liquid immersion shall be measured on three AN6230-7 O-rings by Method 6211 of FED-STD-601. The immersion period shall be 70 hours at 212°±2°F. The average percent change in volume of the three O-rings shall be reported.

4.2.4 Change in volume after aging in MIL-H-19457 fluid, or in Medium No. 3 fluid, followed by exposure to air pressure. Four AN6230-7 O-rings shall be weighed individually in air (W_1), and then weighed individually in distilled water (W_2). The O-rings shall be dried and immersed in the fluid for 70 hours at 212°F. At the end of this period, the O-rings shall be removed from the fluid, cooled, dipped into petroleum ether and wiped dry. The O-rings shall then be placed in a high-pressure container, and subjected to 5200 psig air pressure for 96 hours at room temperature. At the end of this period, the air pressure in the container shall be lowered to 0 psig in less than 15 seconds. At 60±2 minutes after releasing the pressure, the O-rings shall be weighed individually in distilled water (W_4). They shall then be dried and weighed individually in air (W_3). All weighings shall be made on a balance with an accuracy of at least ±10 milligrams and a sensitivity of at least ±2 milligrams. The percent change in volume shall be calculated from the following equation:

$$\frac{(W_3 - W_4) - (W_1 - W_2)}{W_1 - W_2} \times 100 = \text{volume change, \%}$$

The average percent change in volume of the four O-rings shall be reported.

4.2.5 Corrosion and adhesion. Eight AN6230-7 O-rings shall be prepared for corrosion testing by conditioning them in a chamber maintained at 92% minimum relative humidity and at 75°±5°F for 72 hours minimum. The O-rings shall then be washed with ordinary hand soap and water, rinsed in clear water, and wiped dry.

4.2.5.1 Plates of the metals listed below shall be polished to a surface roughness not to exceed 15 microinches rms finish. The plates shall be washed with solvent naphtha and wiped dry. The metals shall be as follows:

Aluminum alloy; Specification QQ-A-318, Temper H32
Brass; Specification MIL-B-994, Composition A
Bronze; Specification QQ-P-330, Composition A
Steel; Specification MIL-S-6758, Condition C2

4.2.5.2 Within 15 minutes after washing four of the O-rings, they and five metal plates shall be dipped in fluid conforming to MIL-H-19457 and drained to the drip point. The O-rings and plates shall then be so laid together in a stack that at least two O-rings contact each specified metal. The other four O-rings and five of the metal plates shall be dipped in Medium No. 3 fluid and so laid together in a stack that at least two O-rings contact each specified metal. The stacks shall be held together with a force of 20 to 30 pounds, and left in the humidity chamber maintained at 92% minimum relative humidity and at 75°±5°F for 96 hours minimum.

4.2.5.3 When the stacks are disassembled, the tendency of the O-rings to adhere to the metal surfaces shall be noted.

4.2.5.4 The surfaces of the plates which were in contact with the O-rings shall be wiped free of immersion fluid and scrubbed lightly with methyl ethyl ketone. Any pits, eroded marks or deposits remaining after this process, which are visible through a microscope of approximately 10X magnification, shall be construed to be corrosion. Discoloration or staining shall not be considered detrimental.

PROPERTIES OF STOCK 377-112 AND PROPOSED SPECIFICATION REQUIREMENTS
(Sheet 1 of 2)

Tests[1]	Stock 377-112	Proposed Specification Requirements
Initial properties		
Tensile strength, psi	2140	Min. 1700
Ultimate elongation, %	140	Min. 100
Stress at 100% elongation, psi	1530	
Shore A hardness, 15-second reading[2]	88	88±5
Permanent set, %	9	Max. 12
After 70 hours at 212°F in air		
Tensile strength, psi	2270	
Tensile strength, retention, %	106	Min. 85
Ultimate elongation, %	140	
Ultimate elongation, retention, %	100	Min. 85
Stress at 100% elongation, psi	1550	
Stress at 100% elongation, retention, %	101	
Shore A hardness, 15-second reading	87	88±5
Change in Shore A hardness, points	-1	
Compression set, %[3]	33	Max. 40
After 70 hours at 212 F in Cellulube 220		
Tensile strength, psi	2110	
Tensile strength, retention, %	99	Min. 85
Ultimate elongation, %	160	
Ultimate elongation, retention, %	114	Min. 85
Stress at 100% elongation, psi	1320	
Stress at 100% elongation, retention, %	86	
Shore A hardness, 15-second reading	84	85±5
Change in Shore A hardness, points	-4	
Volume change, %	+5	Max. +8
		Min. 0

(1) All tests performed on AN6230-7 O-rings except as noted.
(2) Hardness measured on 1/4-inch thick by 2 inch diameter specimens.
(3) Compression set measured on specimens consisting of two 1/4-inch thick by 1.129 inch diameter disks plied together.

Mare Island Naval Shipyard, Rubber Laboratory, Report No. 28-10 of 10 July 1962, Unclassified.

SEALS FOR 5200 PSI AIR SYSTEMS, FINAL REPORT, by R. D. Ford and A. E. Barrett

A Viton B stock (377-112) has been developed which is suitable for making seals for 5200 psi air systems.

A specification covering seals for this service has been prepared.

Corrosion of metals by Viton seals was eliminated by washing the seals with soap and water immediately before installation. Dry molybdenum disulfide was found on performance tests to be as satisfactory a lubricant for Viton seals as MIL-L-4343A grease currently used in high pressure air systems.

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